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 Sending - 1. Amendment & Response - 21  
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**OFFICIAL FILING BY FACSIMILE  
 TRANSMISSION ON OCTOBER 3, 2003 TO  
 FACSIMILE #703-872-9318, FOR EXAMINER F. L.  
 EVANS, TELEPHONE 703-308-4805, ART UNIT 2877**

Response 21 pages, Markup 112 pages  
 CIP Replacement Application 84 pages  
 Drawings 21 sheets  
 Total Fax 238

Our Ref. No. P-1259-981

**IN THE UNITED STATES PATENT AND TRADEMARK OFFICE**

In Re Application of:  
 OZANICH

Date: October 3, 2003

Serial No. 09/804,613

Group Art Unit: 2877

Filed: March 12, 2001

Examiner: F. L. Evans

For: AN APPARATUS AND METHOD  
 FOR MEASURING AND  
 CORRELATING CHARACTERISTICS  
 OF FRUIT WITH VISIBLE/NEAR  
 INFRA-RED SPECTRUM

**AMENDMENT AND RESPONSE**

Hon. Commissioner of Patents and Trademarks  
 Washington, D.C. 20231

Dear Commissioner:

In response to the communication from the Examiner dated June 4, 2003, please  
 consider the following:

**Petition for Extension for Response Within the First Month-Fees Due**

The applicant respectfully observes that this response is filed within the first  
 month. The Examiner is hereby authorized to deduct \$55.00 as fees for filing within the  
 first month and to deduct other fees owing from the deposit account of Liebler, Ivey &  
 Connor, P.S./Floyd E. Ivey, 35,552, Deposit account No. 50-0607.

Certificate of facsimile filing  
 on October 3, 2003 by Floyd E. Ivey.  
 Floyd E. Ivey, USPTO 35552,  
 certifies the filing of this document  
 by facsimile transmission 10/3/03.

Application No. 09/804,613

1 regarding Anthocyanin, which is a red pigment, has an absorption band spanning the  
2 500-550 nm region, which improves classification or predictive performance,  
3 particularly for firmness,

4 The spectrometers 170 used in the preferred embodiment have charge-coupled  
5 device (CCD) array detectors 200 with 2048 pixels or channels, but other array  
6 detectors 200, other light detectors 80, including other detector 200 sizes vis-a-vis  
7 array size or other method of detector size characterization, may be used as would be  
8 recognized by one of ordinary skill in the art. One of the two spectrometers 170  
9 monitors the light source 120 intensity and wavelength output directly, providing a  
10 light source reference signal 81 that corrects for ambient light and lamp, detector, and  
11 electronics drift which are largely caused by temperature changes and lamp aging.  
12 The other spectrometer(s) 170 receives the light detector 80 signal output 82 from  
13 one or more light detectors 80 which are sensing light output from one or more  
14 samples 30 and/or one or more locations on a sample 30, e.g., at multiple points over  
15 a single sample 30, such as an apple, or at multiple points over a sample conveyor  
16 295 belt of apples, grapes or cherries, or a different sample 30, e.g., a different lane  
17 on a packing/sorting line, can be measured with each additional spectrometer 170.  
18 Each light sensor, e.g., light detector 80(photodetector 255 or other light sensing  
19 apparatus or method), in the preferred embodiment represents a separate sample 30 or  
20 different location on the same sample 30 or group of samples 30. Spectra from all  
21 spectrometers 170 are acquired, in the preferred embodiment, simultaneously.  
22 Depending on the type of spectrometer, A/D conversion can occur in parallel or series  
23 for each spectrometer (parallel preferred). The computer then processes the spectra  
24 and produces an output. Current single CPU computers process spectra in series. A  
25 dual CPU computer, two computers, or digital signal processing (DSP) hardware can  
26 perform spectral processing and provide output in parallel.

27 In an alternative embodiment spectra from the wavelength region from about  
28 250-1150 nm, the near-infrared spectra, is examined from samples 30, e.g., fruit  
29 including apples. In this particular experiment, a reflectance fiber-optic probe was  
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1 used as the light detector 80. While the spectrophotometer 170 used to collect the  
2 data, i.e., sense the spectrum output 82 from the light detector 80, was a DSquared  
3 Development, LaGrande, Ore., Model DPA 20, one of ordinary skill in the art will  
4 recognize that other spectrometers and spectrophotometers 170 may be used. The  
5 spectrophotometer 170 referenced employed a five watt tungsten halogen light source  
6 120, a fiber-optics light sensor to detect the spectrum or output 82 from the sample 30  
7 and provide the light sensor signal input 82 to the spectrometer 170. Other lamps 123  
8 or light sources 120 may be substituted as well as other light sensors or light detectors  
9 80. The light detector signal input 82 to the spectrometer 170, in this embodiment, is  
10 detected by a charge coupled device array detector 200. The output from the charge  
11 coupled device array detector is processed as described above. Firmness and Brix  
12 were measured using the standard destructive procedures of Magness-Taylor firmness  
13 ("punch test") and refractometry, respectively. In this embodiment the NIR spectra is  
14 detected by an array detector 200 which permits recording or detection of 1024 data  
15 points. The 1024 data points are smoothed using a nine-point gaussian smooth,  
16 followed by a 2nd-derivative transformation using a "gap" size of nine points. Partial  
17 least squares (PLS) regression was used to relate the 2nd-derivative NIR spectra to  
18 Brix and firmness. To ensure that false correlation was not occurring, the method of  
19 leave-one-out cross-validation was used to generate standard errors of prediction. In  
20 cross-validation, the prediction model is constructed using all but one sample; the  
21 Brix and firmness of the sample left out is then predicted and the process repeated  
22 until all samples have been predicted. The validated model can then be used to  
23 nondestructively predict Brix and firmness in unknown whole fruit samples. This  
24 information guides harvest decisions indicating time to harvest, which fruit is suitable  
25 for cold storage, where the fruit is classified from acceptable to unacceptable  
26 characteristics of quality or consumer taste, which fruit to be removed from the  
27 sorting/packing operation as not meeting required characteristics, e.g., firmness, Brix,  
28 color and other characteristics.  
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1        This disclosure of embodiments of an apparatus and method is directed to the  
2 simultaneous measurement and use of more than one spectral region from a sample.  
3 In this embodiment the use of the chlorophyll absorption region and the NIR region,  
4 including the highly absorbing 950-1150 O-H region, is accomplished by exposing  
5 the sample, e.g. apple, to more than one intensity source of light or by exposing the  
6 light detector 80 at more than one exposure time, e.g., a dual intensity source of light  
7 or at least two intensities of light, or by detecting light from a sample with more than  
8 one light detector 80 such that each light detector 80 is sensitive to a different  
9 spectrum, e.g., by filtering one or more light detectors 80 with filtering either between  
10 the sample 30 and the light detector 80 or between the light detector 80 output 82 and  
11 the spectrometer 170 input. Fig. 1 illustrates filtered light sources 120 allowing  
12 exposure of the sample 30 to different light intensities. Fig. 2 illustrated the use of  
13 more than one light detector 80 where filtering between the sample 30 and light  
14 detector 80 allows detection of different spectral regions. Shown in Fig. 3A, where  
15 the light source is a plurality of discrete wavelength LEDs 257, is an embodiment  
16 wherein the sample is exposed to a plurality of light intensities. The intensity of the  
17 light source 120 will be selected to provide light output to the light detector 80 which  
18 will give optimal S/N data in the desired spectral region. In a first pass a light source,  
19 e.g., a lower intensity light source, is used to illuminate the sample, e.g. apple, to  
20 obtain data, with an acceptable S/N ratio, in the 700-925nm region. At higher (>925  
21 nm) and lower (<700 nm) wavelengths, the spectrum is dominated by noise due to the  
22 low light levels and is not useful. In a second pass a higher intensity light source is  
23 selected to illuminate the sample, saturating the detector array at the 700-925nm  
24 regions while obtaining data with an acceptable S/N ratio, in the red pigment region  
25 of 500-600 nm, the chlorophyll region of 600-699nm and in the O-H region of 926-  
26 1000nm. The data from each of the two passes comprises separate data inputs  
27 delivered to an analog to digital converter for computer processing. Same  
28 spectrometer and A/D for benchtop unit, where the two spectra are acquired  
29 sequentially. For on-line, two spectrometers are used, each with its own A/D. In one  
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1 embodiment A/D cards external to the computer are utilized which are serial and are  
2 provided by Ocean Optics. This process is provides for multiple channels into a data  
3 analyzer for analysis by software. In this embodiment Ocean Optics drivers, hereafter  
4 referred to as drivers, accept MS "C" or Visual Basic to 1) determine the spectrum  
5 detected from the sample or 2) subject the data to the predictive algorithm and  
6 produce the output. Display control computer programs or software periodically  
7 requests drivers to deliver the spectrums to be combined. The digital combination  
8 then produces, with standard display software, the output display representing the  
9 entire spectrum ranges detected from the each sample. There may be, for each  
10 sample, multiple spectrum data. For example the spectrum sampling protocol may  
11 seek 50 spectrum samples during each of the multiple passes, e.g., 50 spectrum  
12 samples during the pass subjecting the fruit sample to the lower intensity light source  
13 and separately 50 spectrum samples during the pass subjecting the fruit sample to the  
14 higher intensity light source. The total duration of each pass will be determined by  
15 the speed of the sorting/packing line and may be limited to approximately 5ms per  
16 sample. However, it will be recognized, for all embodiments and sample types, that  
17 other sampling times and strategies will be within the realm of use for the invention  
18 disclosed herein as different samples and different embodiments are employed.  
19 Where the samples being processed, on a sorting/packing line, are apples, there is  
20 expected to be little space between each successive apple. Spectrum obtained from  
21 the space between apples and at the leading and trailing sides of the sample or apple  
22 will be discarded. As the sample, i.e., apple or other fruit, moves under the light  
23 detector 80, the spectrum data detected will be that exiting the sample 30  
24 representative of the portion of the sample 30 constituting the path between the point  
25 of exposure of the sample 30 with the light source 120 and the point of spectrum exit  
26 for detection by the light detector 80. By mathematical inspection of each spectrum,  
27 e.g., automated inspection via a computer, this method can determine whether light  
28 detected by the light detector 80 is from an apple or the empty space between apples  
29 in a sorting/packing line sample conveyor 295. This method can also detect the  
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1 leading and trailing edges of an apple as it passes by the light detector 80 having an  
2 output 82 to a spectrometer 170. From this data, discrimination can occur to select  
3 specific spectra samples which, for example, are expected to be from the midsection  
4 of the sample or apple. Using mathematical inspection of each spectrum (on-line) to  
5 determine if it is a good apple spectrum or a spectrum of the line material. The cycle  
6 detected by the light detector 80 thus, for each sample 30 in the on the sample  
7 conveyor 295 of a sorting/packing line, is composed of an initial segment where the  
8 light detector 80 or pickup fiber is exposed to only ambient light with a light shield  
9 284 between the light detector 80 and the light source 120. As the sample 30, e.g.,  
10 apple, moves into contact with and under the light shield 284, which may for example  
11 be a curtain 285, the leading edge or side of the apple will commence to be revealed  
12 permitting the light detector 80 to detect spectrum output 82 from the apple.  
13 Continued movement of the sample 30 under the light shield 284 exposes the light  
14 detector 80 to spectrum output 82 from the sample 30 until the sample 30 moves to  
15 the point where the trailing edge or side of the sample 30 is remaining exposed to the  
16 light source 120. The sample 30 then moves past the light shield 284 and all light  
17 from the light source 120 is blocked between the light detector 80 and the light source  
18 120. Thus the initial spectra detected by the light detector 80 will be at the leading  
19 edge or side of the sample 30 as it approaches the curtain 285. The intermediate  
20 spectrum measurements, between the initial time at which the leading edge of the  
21 sample 30 is exposed to the light source 120 and the time when the trailing edge or  
22 side of the sample 30 is exposed to the light source 120, will include those where the  
23 light detector 80 or light pickup is optimally positioned to detect spectra most  
24 representative of the characteristics of the light spectra output 82 from the sample 30  
25 as the light source 120 illuminates the sample 30, e.g., apple, other fruit or other O-H,  
26 C-H or N-H materials. In the preferred embodiment, for ease of data processing, the  
27 light detector 80 analog output 82 is converted to digital data by an A/D card.  
28 Computer program or software tests the data for acceptance or discarding. The  
29 criteria for acceptance of each spectrum sample 30 is a predetermined spectral feature  
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1 determined by the expected spectral output 82 of the sample 30, e.g., where the  
2 sample 30 is an apple, i.e., the criteria will be to detect a spectrum from 250 to  
3 1150nm falling within the spectra expected for an apple. The detection of the space  
4 between apples, in the sorting/packing line, will be recognized as not apples. This  
5 spectrum acquired for each sample 30 is the input to the predictive algorithms as  
6 indicated by the flow diagram of Fig. 1C. Multiple spectrum, for example fifty  
7 spectrum, are detected by the light detector 80 for each sample. The computer  
8 program compares each detected discrete spectrum with an expected spectrum from  
9 the particular sample, the spectrum not meeting the criteria are discarded, the retained  
10 spectrum, e.g., 40 - 50 samples, are combined to provide the spectrum which  
11 becomes the input for the predictive algorithm. Multiple spectra from the same apple  
12 are averaged to provide a single average spectrum representing multiple points on the  
13 apple. the apple may be spinning as it travels by the sensor, e.g., clockwise or counter  
14 clockwise in relation to the direction of sorting line travel with better measurement  
15 indicated with counterclockwise motion of the sample, thus giving even greater  
16 coverage of its surface. Once the average absorbance spectrum for a sample is  
17 calculated, the spectrum is multiplied by the regression vector (via a vector  
18 multiplication dot product). The regression vector is obtained from previous  
19 calibration efforts and is stored on the computer. There is a separate regression  
20 vector for each parameter being predicted - e.g., firmness, Brix. The results of the  
21 processing the spectrum output 82 by the predictive algorithms will determine the  
22 predicted characteristics of the sample 30. The characteristics determined for each  
23 discrete sample 30, e.g., apple or other fruit, will be used for decision making in  
24 handling or disposition of the sample 30 including, for example, 1) in the  
25 packing/sorting line different characteristics will be used for sorting and packing  
26 decisions, e.g., by color, size, firmness, taste as predicted by acidity and Brix and 2)  
27 characteristics indicating spoilage may trigger methods of elimination of the  
28 particular sample 30 from the packing/sorting line.

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1           Packing and sorting of apples will likely involve multiple packing/sorting  
2 illumination or light source 120 and light detector 80s for each line. Where the  
3 sample 30 is comprised of smaller fruit, e.g., cherries or grapes, there may be  
4 multiple light sensors with single or multiple light to interrogate or examine and  
5 gather data from a tray of such smaller fruit rather than on the basis of examination of  
6 each discrete cherry or grape. For each sample 30, data is acquired, tested to  
7 determine if the data corresponds to preset criteria with data selected which meets  
8 preset criteria and discarded if it fails to meet preset criteria. Data received by light  
9 sensors is then combined to compose the total spectrum sampled. The total spectrum  
10 is then compared with the predictive algorithm and decisions are made regarding the  
11 sample 30 including, for example, sorting/packing decisions. The results of the  
12 comparison of the total spectrum with the predictive algorithm provides a number or  
13 other output for end use including information for computer directed sorting  
14 equipment.

15           Operation of the light source 120 is enables the rapid acquisition of  
16 reproducible data with good S/N, even in the highly light scattering and absorbing  
17 250-699 nm and the strongly absorbing >950 nm region. The lamp 123 in the  
18 preferred embodiment is a 12-Volt, 75-Watt tungsten halogen lamp. However, other  
19 light sources which may be used include but are not limited to light emitting diode,  
20 laser diode, tunable diode laser, flash lamp and other such sources which will provide  
21 equivalent light source and will be familiar to those practiced in the art. The lamp is  
22 held at a resting voltage of 2-Volts. When a measurement is taken, the lamp is  
23 ramped up to the desired voltage, a brief delay allows the lamp output 82 to stabilize,  
24 then spectra are acquired. After data acquisition, the lamp is ramped down to the  
25 resting voltage. This procedure extends lamp life and prevents burning the sample.  
26 In high speed operations the lamp may always be lighted, e.g., on a high-speed  
27 packing/sorting line or used on harvest equipment, and a light "chopper" or shutter or  
28 other equivalent article or method could be utilized to deliver light to the passing  
29 sample for a determined period of time. The operation of the light source is  
30



1 important in extending lamp life, reducing operating expense and reducing disruption  
2 of operations. The lamp 123 voltage is ramped up and down to preserve lamp 123  
3 life and to lessen the likelihood of burning fruit. A standby voltage to keeps the lamp  
4 123 filament warm. An ambient/room light background measurement is made to  
5 correct for the dark spectrum, which may include ambient light. It is stored and  
6 subtracted from the sample and reference (if applicable) so that there is no  
7 contribution of ambient light to the sample spectrum, which would affect accuracy..  
8 Dual intensity illumination is employed to: 1) improve data accuracy above 925 nm  
9 and below 700 nm and 2) to normalize path length changes due to scattering. Dual  
10 exposure time increases the likelihood of increased data quality with large and small  
11 fruit. Utilization of more than one light detector 80, with each positioned at different  
12 distances from the sample, will likewise increase the ability to obtain increased data  
13 quality throughout each portion of the spectrum from approximately 250nm to 1150  
14 nm.

15 Other steps in determining predictive algorithms included reference  
16 determination of pH using electrode measurement and reference determination of  
17 total acidity using end-point titration of extracted juice. Correlation between the NIR  
18 spectra and the reference data (pH and total acidity) was conducted. Methods known  
19 to those practiced in the art such as partial least squares (PLS) are used to determine  
20 the correlation of the NIR spectrum with a chosen parameter such as pH.. Once  
21 correlation is established, PLS is used to generate a regression vector from the  
22 calibration samples. This regression vector is then used to predict sample properties  
23 by taking the dot product of the sample spectrum and regression vector. NIR analysis  
24 can be carried out directly on the juice yielding very high correlations with Brix, pH,  
25 and total acidity. A commercially available "dip probe" is used that is a common  
26 item available from optical fiber fabricators or from companies involved in process  
27 analysis. In addition to the use of PLS for quantifying Brix, firmness, pH and acidity,  
28 Principal Components Analysis (PCA) was performed on the NIR spectral data. PCA  
29 differs from PLS in that no reference data is required. PCA allows classification of  
30

1 firm vs. soft apples and low pH vs. high pH samples. This classification algorithm is  
2 sufficient to achieve the goal of product segregation. Using PCA, poor quality fruit  
3 can be removed from a batch and the highest quality fruit can be segregated into a  
4 premium class. Poor quality fruit was observed to often have a higher pH level than  
5 good quality fruit.

6 Fig. 4 illustrates an alternative embodiment of the disclosure and includes at  
7 least one light source 120 transmitted by a transmitting article, for example a fiber  
8 optic fiber or other equivalent article for transmitting light; a sample 30 having an  
9 sample surface 35; input mechanism of positioning light from the at least one light  
10 source 120 proximal the sample surface; at least one illumination detector; output  
11 mechanism of positioning the at least one illumination detector proximal the sample  
12 surface; the at least one light source 120 and the at least one illumination detector  
13 may be positioned in relation to the surface or against the surface by a positioning  
14 article provided, for example, by a positioning article spring biased against the  
15 surface of the sample; the pressure against a sample surface, by an at least one light  
16 source 120 or an at least one illumination detector, will be limited by surface  
17 characteristics of the sample and/or the character of the measurement process, i.e.,  
18 pressure may be reduced where a sample is subject to surface damage or where the  
19 measurement process is in at high speed limiting the time permitted for each separate  
20 sample contact. The illumination is transmitted to the surface, for example by fiber  
21 optics or other equivalent manner, and at least one device or method of measuring the  
22 illumination detected from the sample. The light source, for the disclosure herein  
23 may be a lamp, which for example, but without limitation, may be a tungsten halogen  
24 lamp or the equivalent, which may produce a spectrum within the range 250-1150 nm  
25 and have a filament temperature of of 2500 to 3500 degrees kelvin; other broadband  
26 spectrum lamps may be employed depending upon the sample 30, characteristics to  
27 be predicted, and embodiment utilized; the at least one device or method of  
28 measuring the illumination may be a spectrometer having at least one input; the at  
29 least one spectrometer may include, for example, a 1024 linear array detector with  
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1 those of ordinary skill in the art recognizing that other such detectors will provide  
2 equivalent detection; the at least one illumination detector may be a light pickup fiber  
3 or other equivalent detector including for example a fiber optics light pickup; the at  
4 least one illumination detector collects a spectrum which is received by the at least  
5 one spectrometer input; the sample in this embodiment is from the chemical group of  
6 CH, NH, OH or the physical characteristics of firmness, density, color and internal  
7 and external defects. Additionally, the light source 120 may comprises a plurality of  
8 illumination fibers. In this embodiment a plurality of illumination fibers may be  
9 arrayed such that each of the plurality of illumination fibers is equidistant from  
10 adjacent illumination fibers; the at least one illumination detector may, in this  
11 embodiment, be positioned centrally in the array of illumination fibers. In an  
12 embodiment of this disclosure, the plurality of illumination fibers may, for example,  
13 be comprised of 32 illumination fibers and the light source 120 may be provided, for  
14 example, by a 5w tungsten halogen lamp or other equivalent light source or by a  
15 plurality of illumination sources provided for example by at least two light sources  
16 such as, for example, at least two 50 Watt light sources. Illumination sources may be  
17 composed, for example, of sources having a focusing ellipsoidal reflector with  
18 cooling fan. In this embodiment the at least one illumination detector may comprise  
19 a plurality of light detectors 80, which may for example, be arrayed such that each  
20 illumination detector is equidistant from adjoining light detectors 80; where at least  
21 two light sources are positioned are employed, they may for example be positioned  
22 45 degrees relative to the illumination detectors. in the array of illumination fibers. In  
23 an additional embodiment of this disclosure, a plurality of light detectors 80 may be  
24 comprised of twenty-two illumination detectors. An embodiment of the disclosure  
25 may be comprised of at least one light source 120 composed of a 5 w tungsten  
26 halogen lamp; the at least one illumination detector is a single detection fiber; the  
27 light source 120 is positioned against the sample 30 degrees distal to the detection  
28 fiber. If the measurement of the sample surface is made in a non-contacting manner,  
29 an alternative embodiment may include a polarization filter between the light source  
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1 120 and the sample, provided, for example by a linear polarization filter or an  
2 equivalent as understood by one of ordinary skill in the art; a matching polarization  
3 filter is positioned between the at least one illumination detector and the sample,  
4 which may be provided, for example by a linear polarization filter rotated 90 degrees  
5 in relation to the polarization filter between the light source 120 and the sample.

6 The method described above, which uses wavelengths of both visible  
7 radiation (250-699 nm) specifically chosen to include the absorption band for yellow  
8 color pigments (250-499nm), red color pigments (500-600 nm) and green pigments  
9 or chlorophyll (601-699 nm), as well as NIR (700-1150 nm) radiation to correlate  
10 with Brix, firmness, pH, acidity, density, color and internal and external defects can  
11 be carried out using a variety of apparatuses.

## 12 ADDITIONAL DETAILED DESCRIPTION

### 13 Overview of calibration of visible/NIR sensors:

14 Required calibration was addressed in the Parent Application 09/524,329, in  
15 paragraphs, identified by page/line by pn/ln, as follows: 1/18; 3/17, 22, 28; 4/2; 8/8;  
16 9/4; 9/14; 12/16; 16/8; 22/5; 31/21; 33/19; 39/10; 43/4; 47/1; 52/13 etc. Calibration  
17 of spectroscopic maturity and quality sensors involves building algorithms that relate  
18 the visible and near infrared spectrum of an individual fruit or vegetable to one or  
19 more of the following: Brix (including, but not limited to sugar content, or sweetness,  
20 or soluble solids content); acidity (including but not limited to total acidity, or  
21 sourness, or malic acid content or citric acid content or tartaric acid content); pH;  
22 firmness (including but not limited to crispness or hardness); internal disorders or  
23 defects including but not limited to watercore, browning, core rot, insect infestation.  
24 Furthermore, the individual property data collected above can be combined as  
25 follows: using the ratio of the sugar content to acid content to better predict eating  
26 quality, taste, sweet/sour ratio; using the combined data from two or more of the  
27 following: sugar content, acid content, pH, firmness, color, external and internal  
28 disorders to better predict eating quality.

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1        **Integrating visible/NIR sensors with packing, sorting and conveyance**  
2        **systems and synchronizing data acquisition with product location/position to**  
3        **optimize collection of sample data, and reference and standardization data.**

4        Sensing sample data including the presence or absence of a sample was  
5        addressed in the parent in paragraphs, identified by page/line by pn/ln, as follows:  
6        20/20; 36/8 etc. Using spectroscopic sensors for measuring fruits and vegetables  
7        while in motion on a sample conveyor 295 system in sorting and packing warehouses  
8        is illustrated in Fig. 10 and Fig. 10A and is done as follows: The presence or absence  
9        of a sample 30 and the position/location of the sample 30 relative to the point of  
10       spectrum measurement is determined using one or more of the following means: 1)  
11       sample 30 position determination means and or sample conveyor 295 position  
12       determination means, provided for example by an encoder or pulse generator 330, as  
13       seen in Fig. 9, integral to the sample conveyor 295 and detecting sample conveyor  
14       295 movement, provides one or more electronic or digital signals to a CPU 172  
15       which initiates, by computer program control, control signals to initiate and stop  
16       acquisition of spectra, 2) the spectrum itself is automatically inspected using  
17       computer programs or programmed hardware, e.g., digital signal processors, to  
18       determine if the sample 30 being measured is at the optimal location(s) for spectrum  
19       measurement, 3) a proximity sensing means 340, including proximity sensors of, but  
20       not limited to, magnetic, inductance, optical, mechanical sensors; and also known as  
21       object presence sensors, such as thru-beam or reflectance sensors 341, is used to  
22       provide information about the position, i.e., orientation or location of the product on  
23       the packing or sorting line relative to the NIR sensor, e.g., light detector 80, and/or  
24       size of the sample 30, such proximity sensing means 340 and their use being of  
25       common knowledge to those practiced in the art of industrial processing object  
26       presence sensing. The proximity sensing means 340 can be placed 1, 2, 3 or ...n  
27       units of length, e.g., cups or pockets or conveyor belt length, before the NIR sensor,  
28       e.g., detector 80, to indicate if 1, 2, or 3 or...n more empty spaces, e.g., cups or  
29       pockets or a defined and known length of conveyor belt, are present in sequence, thus  
30

1 allowing a greater amount of time for performing dark spectra and/or reference  
2 spectra and/or standard/calibration samples. Using one or more of the above  
3 methods, the presence or absence of sample(s) 30 is determined over a defined length  
4 of the particular sample conveyor 295 system. If sample(s) 30 is present, multiple  
5 visible and near-infrared spectra are acquired as the sample 30 passes by the light  
6 source 120 lamp(s) 123 providing light detector output 82 and spectrometer(s) 170  
7 detector 200 input; such light collection may be achieved using a collimating lens 78  
8 and or other light transmission means including for example fiber-optics to transfer  
9 the light that has interacted with the sample 30 to the spectrometer(s) 170 detectors  
10 200. If no sample 30 is present, other reference measurements are made to improve  
11 stability and accuracy such as previously mentioned dark spectra, reference spectra  
12 (lamp intensity and color output), and standard/calibration samples, which may be  
13 optical filters or polymers or organic material with known and repeatable spectral  
14 characteristics. Measurements that are made when no sample is present include, but  
15 are not limited to 1) measuring a reference spectrum (intensity vs. wavelength) of the  
16 light source(s), 2) measuring the dark current (no light conditions) of one or more  
17 spectrometer(s) 170 detector(s) 200, including but not limited to the sample  
18 spectrometer(s) 170 and the reference spectrometer(s) 170, and 3) standard or  
19 calibration samples or filters 130 or material.

20 **Obtaining a spectrum of the lamp(s) for determining reference light**  
21 **output and obtaining baseline dark current spectra from detector(s). Both**  
22 **reference and dark spectra are used with sample spectrum to calculate the**  
23 **product's absorbance spectrum.**

24 Reference to reference, baseline and dark spectra was addressed in the parent  
25 in paragraphs, identified by page/line by pn/ln, as follows: 12/18; 39/10; 52/14 etc.  
26 The reference measurements to account for changes in light source intensity or color  
27 output can be obtained using a reference light transmission means 320, e.g., a fiber-  
28 optic bundle which may be furcated, a light pipe or other means of transmitting light,  
29 with a common end 322 providing input to a reference spectrometer 170, and, where  
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1 furcated, one or more branched ends 81, each of which is mounted by means to allow  
2 only light from the light source 120 lamp(s) 123 to enter the reference light  
3 transmission means 320. A light shutter 300 is placed between each light source 120  
4 lamp 123 and each reference light transmission means 320. The at least one light  
5 shutter 300 can be opened and closed separately by shutter control means 305  
6 including, for example, driven by a linear actuator or rotary solenoid or other  
7 mechanical or pneumatic device, or all at once.

8 Each light source 120 lamp 123 in the system can be measured separately to  
9 determine if it is faulty or if it will soon need replacement based on a stored intensity  
10 vs. wavelength spectrum profile. The combined intensities from the reference light  
11 transmission means 320 is used as the reference spectrum for purposes of calculating  
12 an absorbance (or  $\log 1/R$ ) spectrum, which is linear with concentration (e.g., percent  
13 Brix or acidity or pounds of firmness, etc.).

14 Closing all of the light shutters 330 of the reference light transmission means  
15 320 allow a dark current (no light condition) measurement of the spectrometer 170  
16 detector(s) 200. The dark current is largely affected by temperature and must be  
17 periodically measured and its intensity value at each wavelength (or detector) pixel  
18 subtracted from the reference spectrum obtained with the shutters 330 open.

19 The sample spectrometer's 170 detector 200 dark current must also be  
20 periodically measured by closing light shutters 330 that are placed between the light  
21 source and the sample 30, or between the sample 30 and the sample spectrometer  
22 light collection fiber, seen here as detector 80 and detector output 82, or between the  
23 light collection fiber and the spectrometer 170. Similarly to the reference  
24 measurement, the dark current of the sample spectrometer 170 must be subtracted  
25 from the sample spectrum obtained with the shutters 330 open. It will be appreciated  
26 that reference measurement must be made with respect to the spectrometer 170 used  
27 for light source 120 lamp 123 measurement as well as for the spectrometers 170 used  
28 to acquire detector 80 spectrum output 82 as processed in the computer program

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1 controlled CPU 172 in association with algorithms for the characterization of samples  
2 30.

3 The reference measurement, utilizing a shutter means, is demonstrated in Fig.  
4 9. Fig. 9 is an elevation depicting an additional embodiment of the invention  
5 demonstrating at least one light detector 80 having at least one output 82 to at least  
6 one spectrometer 170 having at least one detector 200. At least one colluminating  
7 lens 78 intermediate the at least one light detector 80 and a sample 30. The at least  
8 one light detector 80 positioned to detect light from the sample 30. At least one light  
9 source 120 lamp 123; a shielding means intermediate the at least one light source 120  
10 lamp 123 and a sample 30 conveyed by sample conveyor 295. At least one aperture  
11 310 in the shielding means to allow illumination of the sample 30 by the at least one  
12 light source 120 lamp 123. It will be appreciated by those of ordinary skill in the  
13 instrument containment arts that an instrument case or container will be a means of  
14 mounting the elements of the disclosed invention in all its embodiments. It will be  
15 appreciated that a case 250 may provide shielding and mounting means for the  
16 invention. At least one light interruption means intermediate the at least one light  
17 source 120 lamp 123 and the at least one aperture 310. Light interruption means  
18 provided, for example, by light shutter 300 means. The at least one light shutter 300  
19 operable by at least one shutter control means 305, e.g., linear actuator or rotary  
20 solenoid operated by means, e.g., mechanical driven by electrical, pneumatic,  
21 hydraulic or other power means or other shutter means including for example liquid  
22 crystal screen operated by means. The at least one shutter control means 305  
23 receiving control signals from at least one CPU 172 having at least one shutter  
24 operating control output 307. At least one reference light transmitting means 81  
25 including, for example, fiber-optics including bifurcated fiber-optics, receiving  
26 reference light output from the at least one light source 120 lamp 123. At least one  
27 reference light interruption means, comprised for example of shutter 301,  
28 intermediate the at least one light source 120 lamp 123 and the at least one reference  
29 light transmitting means 81. The at least one reference light shutter 301 operable by  
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1 at least one shutter control means 305, e.g., linear actuator or rotary solenoid operated  
2 by means, e.g., mechanical driven by electrical, pneumatic, hydraulic or other power  
3 means or other shutter means including for example liquid crystal screen operated by  
4 means. The at least one reference light shutter 301 shutter control means 305  
5 receiving control signals from at least one CPU 172 having at least one shutter  
6 operating control output 307. The at least one reference light transmitting means 81  
7 providing an input to the at least one spectrometer 170 detector 200. The at least one  
8 CPU 172 providing at least one lamp power output 125 to the at least one light source  
9 120 lamp 123. The at least one spectrometer 170, receiving input from at least one  
10 reference light transmitting means 81 having at least one output 82 received as in  
11 input to the at least one CPU 172. The spectrometer output 82 capable of A/D  
12 conversion to form input to the at least one CPU 172. The at least one spectrometer  
13 170, receiving input from at least one detector output 82 received as in input to the at  
14 least one CPU 172. The spectrometer output 82 capable of A/D conversion to form  
15 input to the at least one CPU 172. Mounting means to light sources 120 lamps 123,  
16 detectors 80, shutters 300, shutter control means 305, reference light transmitting  
17 means 81 and case 250. Encoder/pulse generator 330 input to CPU 172 providing  
18 sample conveyor 295 movement data. Computer program to operate CPU 172 in  
19 data collection and control functions.

20 A reference measurement of the light source 120 lamp(s) 123 intensity vs.  
21 wavelength output can also be obtained using reflecting means 360, as seen in Fig.  
22 11, including but not limited to, for example, mirrors or other reflecting or diffusing  
23 material, including roughened aluminum, gold, Spectralon®, Teflon, ground glass,  
24 steel. Reflecting means 360 will be positioned to reflect light source 120 lamp 123  
25 light to a detector 80 having an output 82 received by a spectrometer 170 detector  
26 200. A collimating lens 78 may be positioned intermediate the detector 80 and the  
27 light reflected by the reflecting means 360. Reflecting means 360 may be positioned,  
28 e.g., inserted via an aperture 310, for example where a case 250 is utilized, when a  
29 reference measurement is to be made as dictated by reflecting control means 308 as  
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1 an output from a CPU 172. The CPU 172, via means, will detect the presence or  
2 absence of a sample 30 and, when a sample 30 is absent for "n" time increments or  
3 sample conveyor 295 movements will provide a reflecting control means 308 control  
4 signal to reflecting position means 306, e.g., linear actuator or rotary solenoid  
5 operated by means, e.g., mechanical driven by electrical, pneumatic, hydraulic or  
6 other power means. The reflecting means 360 capable of being withdrawn as dictated  
7 by reflecting control means 308 as an output from the CPU 172 when reference  
8 measurement is to be ceased and spectra measurement of a sample 30 resumed.

9 A light reflecting or diffusing body for obtaining the reference spectrum may  
10 also be obtained by mechanical insertion of reference means 430, as seen in Fig. 12  
11 and Fig. 13, in or near the location where actual sample 30 is normally measured,  
12 which is between the light source 120 lamp(s) 123 and reference light transmission  
13 means 320 leading to the sample spectrometer 170 detector 200(s). Insertion is by  
14 insertion means including but not limited to an actuator system 400 capable, upon  
15 receiving control signals or means as recognized by those of ordinary skill including  
16 control signals or means provided from a CPU 172, of operation of an actuator 410  
17 causing a piston 420 to extend 421 and retract 422 as seen in Fig. 12 and 13. Power,  
18 including for example electrical, pneumatic, hydraulic and other means, is provided  
19 to operate the actuator by power transmission means 440 as will be appreciated by  
20 those of ordinary skill.

21 A CPU 172, controlled by computer program, is not depicted in Fig. 10, 10A,  
22 11, 12 or 13 as a person of ordinary skill will appreciate such structure from viewing  
23 other drawings presented herein.

24 **Achieving whole product measurement (minimizing errors due to**  
25 **localized measurement).**

26 To improve the measurement of the entire product, two or more light sources  
27 120 lamps 123 and/or detection 80 points are used. The product can be measured  
28 rolling or not rolling with a rolling measurement generally improving whole product  
29  
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1 measurement, while a non-rolling measurement provides better accuracy and  
2 introduces less spectral noise due to movement.

3 As a single fruit or vegetable sample 30 passes by the point of spectrum  
4 acquisition, multiple spectra are acquired, each spectrum representing a different  
5 measurement location or area on the product.

6 **Optimizing signal-to-noise and accuracy with small and large size**  
7 **product.**

8 One or more means may be used to determine the size or weight of the  
9 individual fruit or vegetable sample 30. Means for determining product size includes,  
10 but is not limited to 1) a separately determined weight or mass using sensors common  
11 to the industry, 2) utilizing the color sorter or defect sorter data (e.g., from camera or  
12 CCD images), 3) utilizing other size sensors based on magnetic, inductive, light  
13 reflectance or multiple light beam curtains, common to other industries. The relative  
14 size of the sample 30 can then be used to adjust the hardware spectrum acquisition  
15 parameters or the amount of light (by varying the aperture 310 size) to provide an  
16 improved signal-to-noise ratio spectrum for large samples 30 and/or to prevent  
17 detector 80 saturation by light for small product sample 30, e.g., detector 80 exposure  
18 or integration time can be set for longer time periods for large product samples 30  
19 and for shorter time periods for small product.

20 **Improving accuracy by inspection of multiple individual spectra collected**  
21 **from a single product and removing poor quality or "outlier" spectra. Then,**  
22 **calculating the absorbance spectrum from the raw data collected for dark,**  
23 **reference and sample.**

24 Each individual spectrum from the series of spectra acquired for each  
25 individual product sample 30 are then inspected by a computer program or  
26 programmed hardware. Poor quality spectra are deleted from this batch of spectra  
27 and the remaining spectra are used for constituent or property prediction. The  
28 retained spectra of the product are combined with the appropriate reference and dark  
29 current measurements to produce an absorbance spectrum as follows:

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1 Absorbance Spectrum =  $-\log_{10} [(sample\ intensity\ spectrum - sample\ dark$   
2  $current\ spectrum) / (reference\ intensity\ spectrum - reference\ dark\ current\ spectrum)]$   
3 i.e. the absorbance spectrum is equal to the negative logarithm (base 10) of the ratio  
4 of the dark current corrected sample spectrum to the dark current corrected reference  
5 spectrum.

6 All of the absorbance spectra for each product sample 30 can then be  
7 combined to produce a mean or average absorbance spectrum of the product sample.  
8 This average absorbance spectra can then be used to compute the component or  
9 property of interest based on a previously stored calibration algorithm. Alternatively,  
10 each absorbance spectrum can be used individually with a previously stored  
11 calibration algorithm to compute multiple results of the component or property of  
12 interest for an individual product, followed by determination of the average or mean  
13 component or property value computed by summing all of the values and dividing the  
14 resultant sum by the number of absorbance spectra used.

15 Method for measuring samples and importance of linking location on  
16 product where visible/NIR data was collected with the same location that will be  
17 measured by the laboratory reference technique.

18 Calibration is performed as follows: 1) Spectra of product sample 30 are  
19 measured and absorbance spectra (corrected for reference and dark current) are  
20 stored, 2) Standard laboratory measurements (which are often destructive) are made  
21 on the product sample 30. Note: it is important to the success of the NIR method  
22 that the portion of the sample 30 that is interrogated between the light source(s) 120  
23 lamps 123 and light collection(s) detectors, e.g., light detectors 80, leading to the  
24 spectrometer(s) 170 detectors 200 is the same as that portion measured by the  
25 standard laboratory technique.

26 For many sample conveyors 295 that are used for whole fruit and vegetable  
27 sorting and packing operations, the product can be transported past the NIR  
28 measurement location rolling or not rolling. If absorbance spectra are collected from  
29 the product as it is rolling, the exact location of any one measurement (one spectrum)  
30

1 is not usually known, and therefore the entire product (as opposed to one localized  
2 spot) must be analyzed for the component or property of interest. If calibration  
3 algorithms are constructed in this way (using measurements of rolling product), all of  
4 the retained spectra for that individual product are averaged to produce an average  
5 absorbance spectrum and the total product component or property is assigned to this  
6 one absorbance spectrum.

7 Because most fruits and vegetable are heterogeneous and vary in component  
8 level with location, it is preferable to develop a calibration model on product sample  
9 30 that is not rolling so that each acquired spectrum is from a known physical  
10 location on the product sample 30. Then, laboratory measurements are made on the  
11 same portion of product sample 30 that spectra were taken from. When this  
12 procedure is used, a whole fruit or vegetable sample 30 may be separated, e.g., cut or  
13 sliced, into smaller sub-portions prior to laboratory analysis. These smaller sub-  
14 portions each correspond to NIR data collected over the same locations within the  
15 product sample 30; the time period of NIR data acquisition can be adjusted to shorter  
16 or longer times, corresponding to the measurement of smaller or larger product  
17 samples 30, respectively. In this case, each sub-portion of the product sample 30 will  
18 have one or more spectra associated with that particular location. The laboratory  
19 determined component or property is then assigned to each spectrum or spectra from  
20 that particular location.

21 Mathematical processing is performed on absorbance spectra prior to  
22 conducting statistical correlation analysis and calibration model building.

23 Absorbance spectra are pre-processed using a bin and smooth function.  
24 Partial least squares analysis (or variants thereof such as piecewise direct  
25 standardization) are then used to relate the processed absorbance spectrum to the  
26 assigned component and property values such as Brix, acidity, pH, firmness, color,  
27 internal or external disorder severity and type, and eating quality.

28 Method to minimize the number of samples needed to develop a  
29 calibration model.

30

1 To minimize the number of calibration samples that are necessary, the  
2 following method can be used: 1) spectra are collected on all test samples 30, 2) prior  
3 to destructive laboratory measurements, principal components analysis (PCA) is  
4 performed on the absorbance spectra, 3) Resultant Score plots from PCA (e.g., Score  
5 1 vs. Score 2, Score 3 vs. Score 4, etc.) are then generated, 4) A subset of the original  
6 samples (e.g., 40% of the original number of samples) are selected from the Score  
7 plots in either a random fashion or by selecting samples that, as a group, yield a  
8 similar range, mean and standard deviation of score values compared to the entire  
9 group of original samples 30.

10 Calibration updates are periodically required to maintain measurement  
11 accuracy, particularly with agricultural product samples 30 that can vary in  
12 composition with growing conditions and variety. Several methods can be used to  
13 minimize the efforts of calibration updates. As fruit or vegetable samples 30 are  
14 analyzed in a packing and sorting warehouse, their visible/near infrared spectra can  
15 be examined by software to determine if the sample qualifies as a potential  
16 calibration update sample 30. Good calibration update samples 30 will cover low to  
17 high component values and will have Score values that cover the same range as the  
18 original sample's 30 Score values.

19 While a preferred embodiment of the present disclosure has been shown and  
20 described, it will be apparent to those skilled in the art that many changes and  
21 modifications may be made without departing from the disclosure in its broader  
22 aspects. The appended claims are therefore intended to cover all such changes and  
23 modifications as fall within the true spirit and scope of the disclosure.

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